Synopsis

Many High Voltage Direct Current Transmission Systems (HVDC) with two terminals are effecting efficient power transfer and improved AC system performance In view of this, point to point links are being interconnected to form a Multi Terminal DC transmission system (MTDC) This offers more flexibility in operation, increases the overall efficiency of the power transmission and significantly improves the AC system performance With the conventional naturally commutated inverters, it is very difficult to feed into weak AC systems and impossible to feed into dead loads These problems can be overcome by using forced commutated converters With the development of high power and high frequency switching devices the time is ripe to investigate the suitability of using PWM converters in MTDC-AC system The other problem addressed in this thesis is on-line monitoring and control of MTDC-AC system which is highly involved and compute intensive task Further, with the recent developments in the area of high power computing and information sciences, a number of new paradigms like artificial intelligence (AI), expert systems etc , are available to infuse intelligence into control systems Hence MTDC system controls with intelligent controllers and PWM converters require sophisticated computer system which can handle fast computation and also a large number of input output The present work is thus aimed at the ***development of a totally scalable real-time intelligent system for on-line monitoring and control of MTDC-AC system with Sine-wave Pulse Width Modulated (SPWM) converters***

The survey of literature brings out the need for research and development on the following issues to enhance the performance of the existing MTDC-AC transmission networks

A) <u>PWM converters for DC transmission</u>

The forced commutated inverter can supply power to a weak AC system efficiently, and even to dead-loads At the same time, it is able to control major reactive power such that AC bus voltage is maintained constant Further, PWM control yields high quality sinusoidal voltages and line current can be controlled to achieve unity power factor Although several types of PWM converters are proposed in power electronics literature, applicability of these converters for DC transmission is still in its infancy With the development in high voltage, high frequency switching devices, the time is ripe to investigate the use of PWM converters for HVDC applications

B) Real-Time controllers for HVDC systems

Control of DC transmission system is hierarchical in nature starting from firing pulse generator, bridge controls, pole controls and overall master control Control of such a complex system has been carried with microprocessor based systems, multiprocessor based controllers, micro controllers and multiple digital signal processors Further to this, MTDC systems are highly scalable and hence the same is desirable with the controllers The need for higher computing power is fast growing with the introduction of PWM converters and intelligent controllers

C) Development of real-time controllers and validation

The final implementation of the controllers developed need validation of their performance in real-time This is done with the help of physical simulators, or on the test system There is a need for the development of such a physical simulator for MTDC-AC systems using PWM converters Also there is a requirement for a system which can allow on-line monitoring and control and at the same time allow user interaction with the controller This will help in tuning of the controllers and evaluation of the controller performance in real-time

In view of this, following are the objectives of this thesis

- **Application of SPWM converters for MTDC-AC systems.**
- **Development of a real-time system for on line monitoring and control of MTDC-AC system with SPWM converters.**
- **System for development of real-time controllers and their performance verification in real-time.**

These objectives have been broadly realised and are described below

With the help of PSPICE simulation, choice of appropriate PWM technique for DC transmission systems is carried out From this simulation, we have also derived the switching sequences, filter components, harmonic estimation under different switching strategies and optimal switching frequency SPWM technique is selected as it exhibits improved performance for the given application The BOOST type of voltage source converter using six switches is employed due to its flexibility in operation and it can be used as rectifier or inverter and also can exercise direct control over the voltage amplitude, voltage angle and frequency With this, it is possible to operate the converters as a power dispatcher or as a DC voltage regulator which constitute the two building blocks of the MTDC system An optimal carrier frequency is used such that it will help in reducing total harmonic distortion and maintaining low switching losses

An application specific parallel processing system with transputers is developed as the real-time controller Transputers are used as they have in-built computation and communication features and also help to build scalable architecture Hence their architecture inherently supports parallel processing and easy interface with any host system and peripheral devices A high speed data acquisition system which has a conversion rate of 10 mega samples per sec , digital input/output, programmable timer, on-board dual-ported RAM, simultaneous sample and hold circuits for 32 channels and a transputer interfaced for communication and control logic is developed A novel Firing Pulse Generator (FPG) is developed for converter grid control With this FPG circuit, strict dependency on the controller action and central computer communication is reduced A vector signal processor with a peak performance of 47 MFLOPS and sustained performance of 37 5 MFLOPS on vector operations is interfaced with the transputer executing the control routines This will help in performing on-line harmonic estimation, digital filtering and various digital signal processing routines in real-time and achieve very sophisticated controls System software is developed using a real-time operating system A timed token protocol is developed to synchronise the various tasks of the controller A two level blackboard based expert system is developed to control and co-ordinate these tasks in real-time

The same system is further upgraded to provide additional facilities like on display of various control system parameters, voltages and currents of the MTDC-AC system, a data logger to record selected parameters for off-line analysis and documentation and user interface via host system This is achieved by including one transputer with a back-end graphic co-processor for display purpose, another transputer with large amount of on-board memory for data logging and another transputer for the host interface to provide user interface With this system it is now possible to develop real-time controllers and also test their performance in real-time This upgradation also illustrates scalability of the proposed system with the application needs

Scaled down physical models of the SPWM converters are built using BJTs as switching devices The controller is isolated from the power circuit using opto isolators The DC line is simulated using lumped sections The inverters feed into dead load to test the performance of the system for this acute condition

Finally using this controller in conjunction with the simulator we have illustrated the development of various types of controllers like proportional, proportional integral, fuzzy logic controllers and hybrid knowledge based controllers for over all system controls of a four terminal parallel mesh connected MTDC-AC system using SPWM converters The controllers have been subjected to set point tracking and disturbance rejection studies Various fault studies have been carried out to test the real-time performance of these controllers The MTDC-AC system is able to recover from severe faults easily and the response is optimally damped

We have demonstrated the usefulness of such a real-time system and this can serve as a test bench for carrying out further system studies on future generations of controls as well as different topologies of MTDC-AC systems as the need arises